

IN THE SPECIFICATION:

Although the specification as originally filed did not include paragraph numbering, in the previous amendments to the specification, paragraph numbers were used to identify the paragraphs being amended. To ensure that the Patent Office will be able to enter the following amendments correctly, we have included both the paragraph number used in prior amendments and the paragraph position on each page of the specification as originally filed.

Please amend paragraph [0001] (first full paragraph on page 2) as follows:

[0001] This application is a divisional of application Serial No. 09/168,621, filed October 8, 1998, ~~pending~~, now U.S. Patent 6,268,275, issued July 31, 2001.

Please amend paragraph [0002] (second full paragraph on page 2) as follows:

[0002] Field of the Invention: This invention relates generally to semiconductor device manufacturing. More particularly, the present invention is directed to methods and apparatus for handling solder balls in forming ball grid arrays ~~(BGA's)~~, (BGAs).

Please amend paragraph [0003] (third full paragraph on page 2) as follows:

[0003] State of the Art: Integrated circuit semiconductor devices ~~(IC's)~~, (ICs) are small electronic circuits formed on the surface of a wafer of semiconductor material such as silicon. The ~~IC's~~, ICs are fabricated in plurality in wafer form and tested by a probe to determine electronic characteristics applicable to the intended use of the ~~IC's~~, ICs. The wafer is then subdivided into discrete IC chips or semiconductor dice, and then further tested and assembled for customer use through various well-known individual IC die testing and packaging techniques, including lead frame packaging, Chip-On-Board (COB) packaging, and flip-chip packaging (FCP). Depending upon the semiconductor die and wafer sizes, each wafer is divided into a few dice or as many as several hundred or more than one thousand discrete die.

Please amend paragraph [0011] (paragraph bridging pages 3 and 4) as follows:

[0011] In United States Patent 5,620,927 of Lee, a template with an array of ~~through-holes~~ through-holes is placed on the workpiece and solder balls are introduced into the holes by rolling the solder balls across the workpiece surface. The apparatus may be installed on a tilt table to encourage filling of all holes. In United States Patent 4,871,110 of Fukasawa et al., a template having an array of holes is placed on a ball holder with a like array of smaller holes to which vacuum is applied and over which solder balls are rolled. After the array is filled with solder balls, the template and ball holder with balls are removed and the exposed ends of the balls attached to a substrate by e.g., reflow. The template and ball holder are then pulled from the substrate, leaving a ball-grid-array ready for attachment to another substrate or workpiece. A vacuum system is required, and there is no easy way to replace a solder ball onto a bond pad to which a ball did not become attached (~~missing~~ (i.e., missing ball)).

Please amend paragraph [0015] (fourth full paragraph on page 4) as follows:

[0015] The use of a ball pick-up tool with an array of vacuum suction ball retainers to pull up balls from an underlying reservoir and place them on a substrate is disclosed in United States Patent 5,088,639 of Gondotra et al., United States Patent 5,284,287 of Wilson et al., United States Patent 5,445,313 of Boyd et al., United States Patent 5,467,913 of Nemekawa et al., United States Patent 5,615,823 of Noda et al., United States Patent 5,680,984 of Sakemi, United States Patent 5,685,477 of Mallik et al., United States Patent 5,687,901 of Hoshiba et al., and United States Patent 5,695,667 of Eguchi et al. It is known in the art that shutting off the vacuum to release each ball onto the substrate is not always successful, and sometimes balls remain attached to the pick-up tool. Again, there is no easy way to replace a missing ball except with a single ball ~~pickup~~ pick-up tool.

Please amend paragraph [0019] (fourth full paragraph on page 5) as follows:

[0019] The use of ultrasonic vibration to cause solder ball movement in the ball reservoir, and to remove excess solder balls from a vacuum-~~pickup~~ pick-up tool, is taught in United States Patent 5,687,901 of Hoshiba et al.

Please amend paragraph [0023] (second full paragraph on page 6) as follows:

[0023] In a second embodiment, a sphere supply apparatus includes a shuttle plate with the same through-hole pattern as the stencil plate. The shuttle plate closely overlies the stencil plate and is reversibly movable between a first position wherein its through-hole pattern is aligned with the pattern of the stencil plate and a second position wherein the through-hole patterns are non-aligned. In the first position, spheres may drop from the shuttle plate through-holes into the stencil plate through-holes. In the latter position, spheres are prevented from entering the through-holes of the stencil plate. ~~The through-holes~~ through-holes of the shuttle plate may be fed from an overlying open bottom reservoir, which may be fixed to the shuttle plate or fixed in position. The linear movement of the shuttle plate is less than the inter-sphere distance, i.e., pitch, and is generally equal to about one-half of the pitch.

Please amend paragraph [0038] (third full paragraph on page 8) as follows:

[0038] The invention comprises an improved method and apparatus for placing a plurality of conductive spheres ~~12- 12~~, such as preformed solder balls or germanium-~~balls~~ balls, on conductive sites 14 on a surface 16 of a substrate 20. The term "substrate" is used in a broad generic sense herein to include any semiconductor device including a wafer or a packaged or unpackaged bare die, as well as traditional substrates including circuitized boards such as printed circuit boards ~~(PCB's)~~ (PCBs). The method of the invention may be applied to the placement of conductive spheres 12 on any conductive site 14, whether the site, e.g., ~~bond~~ a bond pad, projects from the substrate 20 or is recessed therein. The terms "conductive site" and "bond pad" are used interchangeably herein to denote any conductive site 14 at which a conductive sphere 12 is to be placed.

Please amend paragraph [0040] (fifth full paragraph on page 8) as follows:

[0040] As depicted in drawing FIG. 1, a sphere placement apparatus 10 for placing a plurality of conductive spheres 12 on a substrate 20 comprises a stencil plate or screen 30 and a sphere supply apparatus 50/50A. The substrate 20 is shown with a pattern 22 of conductive sites or bond pads 14 with an interpad pitch 18, wherein the pattern ~~22~~ 22, in this ~~example~~ example, includes all of the bond ~~pads~~ pads 14. The substrate 20 is shown with exemplary registry markers 24 by which the stencil plate 30 and substrate 20 may be accurately aligned to each other. The various components of the invention may be aligned using a mechanical or pattern recognition alignment, or any other type of accurate alignment apparatus as known in the art.

Please amend paragraph [0041] (paragraph bridging pages 8 and 9) as follows:

[0041] A stencil plate 30 of the sphere placement apparatus 10 is a planar plate with upper surface 38 and lower surface 42. An array of through-holes 34 is arranged in a through-hole pattern 32 which corresponds to bond pad pattern 22 of the substrate 20. Through-holes 34 have a diameter 36 which is slightly larger than the mean diameter 28 of the conductive spheres 12, so that the conductive spheres 12 may easily pass through, yet be closely constrained in lateral movement.

Please amend paragraph [0042] (first full paragraph on page 9) as follows:

[0042] The stencil plate 30 has a thickness 40 which is configured and positioned for holding conductive spheres 12 on bond pads 14, such that a sphere supply apparatus 50 moving across the stencil plate 30 does not intercept the placed conductive spheres 12, while preventing more than one conductive sphere 12 from entering each through-hole 34.

Please amend paragraph [0045] (fourth full paragraph on page 9) as follows:

[0045] Referring to drawing FIG. 7, illustrated is a straight through-hole 34 of a stencil plate 30. As depicted in drawing FIG. 8, the through-hole 34 may have a beveled upper edge 72 which enhances movement of conductive spheres 12 into the through-hole 34.

Please amend paragraph [0046] (fifth full paragraph on page 9) as follows:

[0046] The sphere placement apparatus 10 includes a sphere supply apparatus 50 which in this embodiment is a hopper 50A having a lower opening 44 (FIG. 4) by which conductive spheres 12 may drop into through-holes 34 of the stencil plate 30 as the hopper 50A is moved across the upper surface 38 of the stencil plate 30. The hopper 50A has inner walls 46 (FIG. 1) which contain and feed conductive spheres 12 to the stencil plate 30.

Please amend paragraph [0047] (sixth full paragraph on page 9) as follows:

[0047] The lower opening 44 has a width 48 (FIG. 4) equivalent to about ~~2~~ two (2) to about ten (10) sphere diameters 28. Thus, for ~~solder balls~~ conductive spheres 12 having a diameter 28 of 1.0 mm, the lower opening 44 may have a width 48 of about 0.2 cm. to about 1.0 cm.

Please amend paragraph [0048] (paragraph bridging pages 9 and 10) as follows:

[0048] As shown in drawing FIG. 4, the hopper 50A has a lower surface 60 which is spaced from the upper surface 38 of the stencil plate 30 by a short distance 62. Distance 62 is less than one-half (and preferably less than one-third) of the sphere diameter 28, and the stencil plate 30 and hopper 50A may even be in contact. The hopper 50A is controlled to reversibly move across through-hole pattern 32 in direction 68 from a first position 64 beyond one side of the through-hole pattern 32 to a second position 66 beyond the other side of the through-hole pattern 32, dropping conductive spheres 12 into each through-hole 34, and thereby onto each bond pad 14 directly below.

Please amend paragraph [0049] (first full paragraph on page 10) as follows:

[0049] The substrate 20, stencil plate 30, and hopper 50A are each manipulated in robotic action to maintain the desired clearances and alignments, and to move the hopper 50A between first and second positions 64 and 66, respectively.

Please amend paragraph [0050] (second full paragraph on page 10) as follows:

[0050] In the drawings of FIGS. 1-6, the bond pads 14 of substrate 20 are pictured as projecting from the substrate 20. The sphere placement apparatus ~~may~~ 10 may be used for placing conductive spheres 12 onto recessed bond pads 14, as depicted in drawing FIG. 9. Depending on the sphere diameter 28 and the recess depth 74 of the bond pads 14, the stencil ~~plate~~ plate 30 thickness 40 may need to be adjusted to achieve a sufficient plate-to-pad gap 56.

Please amend paragraph [0051] (third full paragraph on page 10) as follows:

[0051] The hopper 50A may have inside ~~wall surfaces~~ walls 46 which are sloping, as in FIG. 4, or parallel, as in drawing FIG. 10.

Please amend paragraph [0052] (fourth full paragraph on page 10) as follows:

[0052] Another embodiment of the sphere placement apparatus 10 is shown in drawing FIGS. 11-13. The substrate 20 and stencil plate 30 are shown as being identical to those already described above. However, the sphere supply apparatus 50 comprises a shuttle plate 80 which underlies a sphere reservoir 90. Sphere reservoir 90 may be attached to the shuttle plate 80, or may comprise a separate structure. Shuttle plate 80 has an upper surface 88 and a parallel lower surface 92, with a third pattern 82 of through-holes 84. The third pattern 82 is substantially the same as through-hole pattern 32, although through-holes 84 may be of somewhat greater diameter 86 than the diameter 36 of through-holes 34. The shuttle plate 80 and sphere reservoir 90 may be configured to reversibly move a short distance in direction 94, i.e., roughly one-half of the interpad pitch 18 (FIG. 4). Thus, the shuttle plate 80 moves from a position where its third pattern 82 is ~~non-~~

~~aligned non-aligned~~ with the ~~stencil plate through-hole~~ pattern 32 (see FIG. 12) to a position where it is aligned therewith (see FIG. 13) for dropping the conductive spheres 12 into through-holes 34 and thus onto the bond pads 14.

Please amend paragraph [0056] (fourth full paragraph on page 11) as follows:

[0056] After a layer 52 is formed on the bond pads 14, the lower surface 42 of a stencil plate 30 and the upper surface 16 of a substrate 20 are aligned to provide a desired ~~plate-to-pad~~ plate-to-pad gap 56 (see FIG. 3).

Please amend paragraph [0057] (fifth full paragraph on page 11) as follows:

[0057] The hopper 50A, having conductive spheres 12 therein, is moved in direction 68 across the through-hole pattern 32 of the stencil plate 30, whereby conductive spheres 12 are dropped into each through-hole 34 to become adhered to the bond pads 14 ~~as~~ (as shown in ~~FIG. 4. FIG. 4).~~

Please amend paragraph [0058] (sixth full paragraph on page 11) as follows:

[0058] At this point in the process, the stencil plate 30 may be tested, either visually or by other methods known in the art, to ensure that all through-holes 34 are filled. If any through-holes 34 are unfilled, the ~~hopper~~ hopper 50A movement may be repeated.

Please amend paragraph [0059] (seventh full paragraph on page 11) as follows:

[0059] Upon filling of all through-holes 34 with conductive spheres 12, the substrate 20 and/or the stencil plate 30 with hopper 50A are moved in direction 70, separating the substrate 20 as shown in drawing FIG. 5 for further manufacturing steps. The next step is typically one of heating the substrate 20 and conductive spheres 12 to cause a reflow of the solder spheres, resulting in conductive spheres 12 fixed to the bond pads 14 as shown in drawing FIG. 6. Where the conductive spheres 12 are not solder, but comprise a metal such as germanium, the sphere

placing method may begin with solder being placed on each bond pad 14, fluxing of the solder surface, and then placement of the conductive spheres 12.

Please amend paragraph [0060] (first full paragraph on page 12) as follows:

[0060] The placement method for the embodiment of drawing FIGS. 11-13 is similar to that of drawing FIGS. 1-4. The steps of pre-applying a layer 52 of flux or sticky material to the bond pads~~14~~ 14, and aligning of the stencil plate 30 with the substrate 20 are the same or similar. Once the prefluxed substrate 20 is properly installed in the sphere placement apparatus 10, the shuttle plate 80 and sphere reservoir 90 are moved from a non-aligned position to an aligned position, whereby conductive spheres 12 fill the through-holes 84 of the shuttle plate 80 and, upon reaching the aligned position (FIG. 13), are dropped into the through-holes 34 of the stencil plate 30 and onto the prefluxed bond pads 14. The substrate 20 may be then separated from the stencil plate 30 and the conductive spheres 12 fixed by reflow to the substrate 20.